Influence of Large-Scale Subsidence on Convective Aggregation

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A series of cloud-resolving model experiments is used to investigate the response of convection to imposed large-scale subsidence. Subsidence is favorable to convective aggregation in a non-linear fashion. In our model configuration, the radiative-convective equilibrium exhibits scattered convection and this non-aggregated stationary state exists also for weak subsidence. For large subsidence, an aggregated stationary state exists and there is a significant range of subsidence intensity for which both aggregated and non-aggregated states co-exist. The aggregated state is, in average, drier than the non-aggregated state and therefore the drying effect of subsidence is weaker on the aggregated than on the non-aggregated state, making the former more resilient to subsidence than the latter. The aggregated state can be analyze in both two-column and moist static energy frameworks, and it appears that the main adjustment to the subsidence forcing is a reduction of the area of the convective patch. We also analyze transient experiments to quantify the contributions of the different physical processes to the aggregation or disaggregation of convection.

Introduction

In some configurations, Cloud-Resolving models in Radiative Convective Equilibrium produce a stationary state with one moist region and one dry region, and an overturning circulation between the two.

Is it relevant to Mesoscale Convective Systems? Convectively-coupled equatorial waves? MJO?

We don't quite know yet.

What happens if there is vertical circulation, forced by remote influences?

Methodology

- Domain: 300 km x 300 km, with 3 km resolution. 25 km of altitude with 47 levels
- I impose vertical velocity everywhere in the domain, used in the vertical advection of energy, humidity, and momentum.
- Divergent horizontal advection is taken to transport the mean humidity from the RCE. **M=1 → 1 kg m-2 s-1 at 400 hPa**
- Different initial conditions.
- Simulations run to stationary state (up to 300 days)

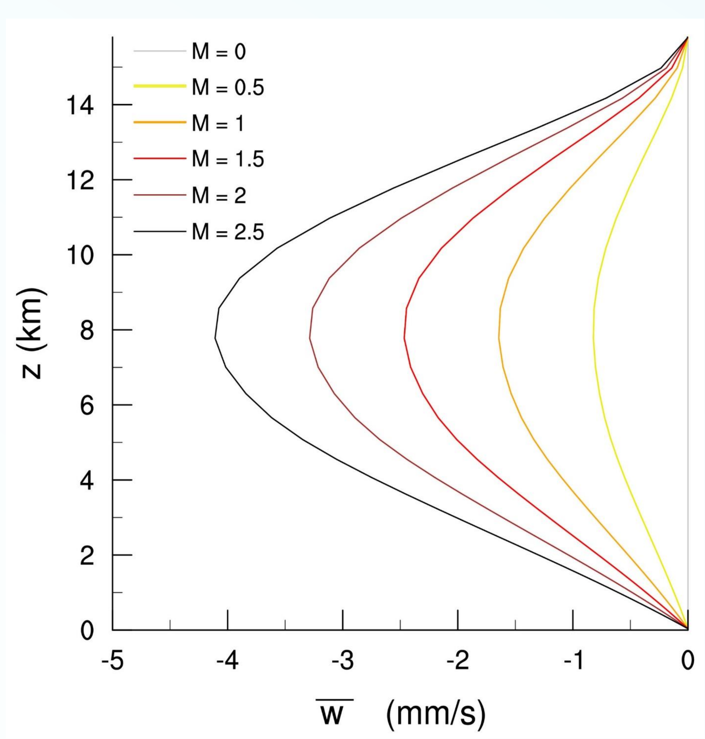

Figure 1: Profiles of imposed vertical velocity for different values of the **subsidence intensity M**. M= 1 corresponds to a downward mass flux of 1 kg m−2s−1, M= 0 is the RCE

- **Aggregated state if PDF of [h] is bimodal**

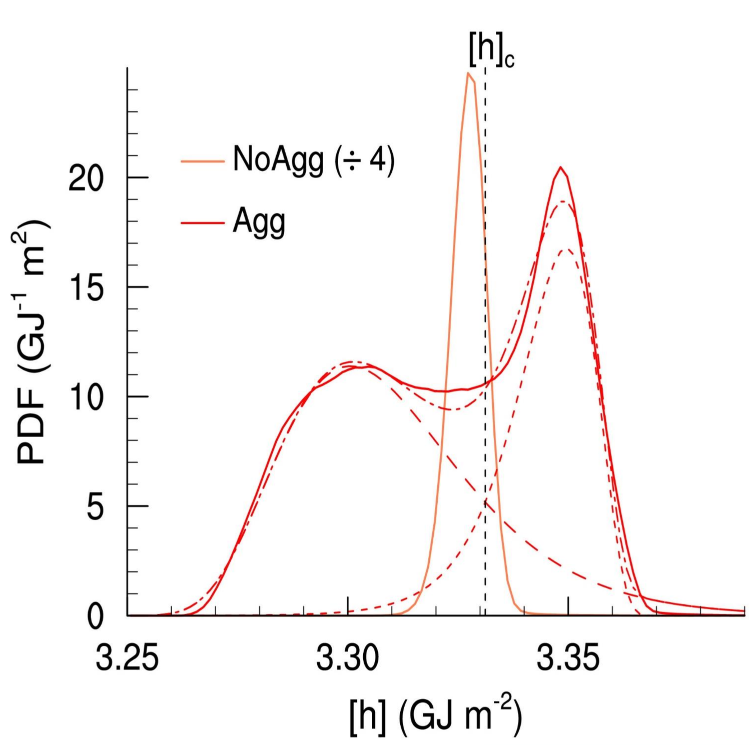

Figure 2: PDF of the column-integrated MSE [h] for the non-aggregated (orange) and the aggregated (red) states as well as its approximation by the sum (red dash-dotted) of two log-normal distributions (red dotted and dashed lines), for M= 1.5. The threshold column-integrated MSE [h]c between the convective and dry regions is indicated (black dotted line).

Results

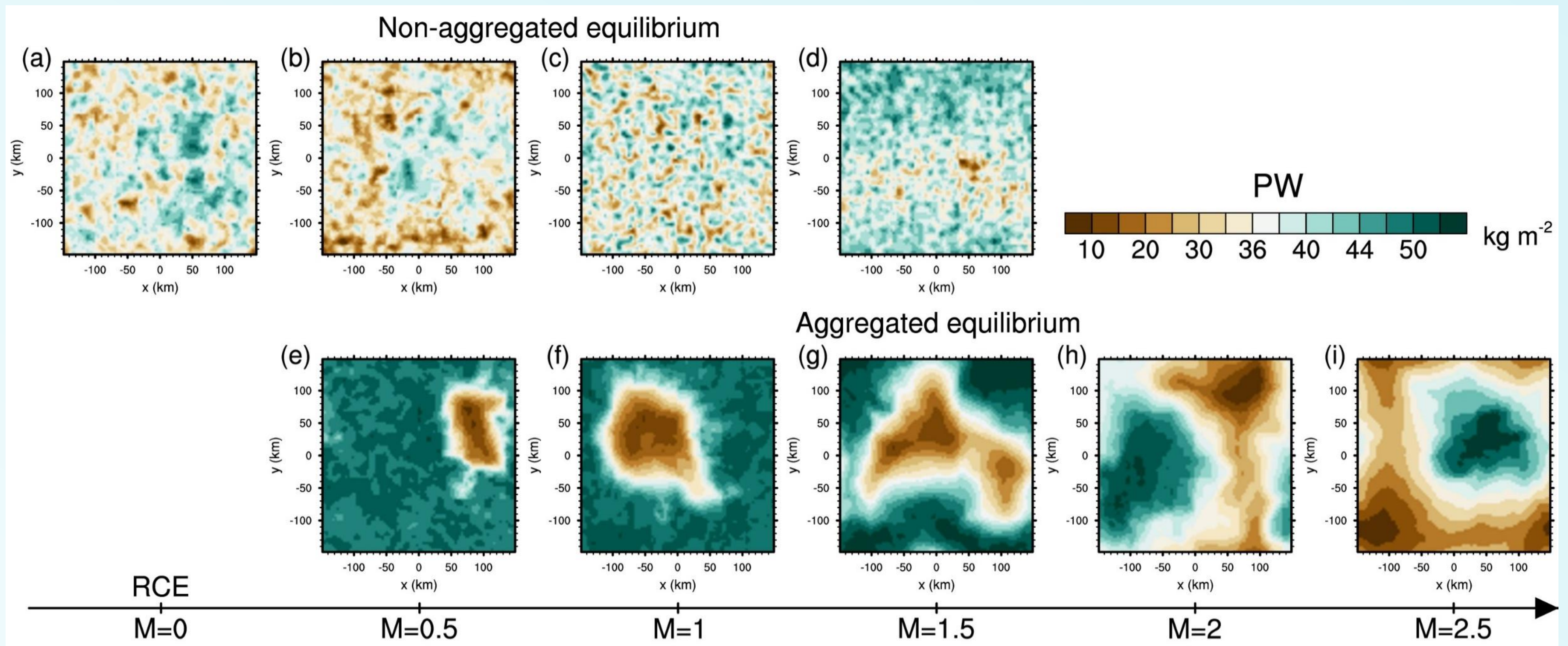

Figure 3: Maps of precipitable water for a typical day in the non-aggregated stationary state (a,b,c,d) and the aggregated stationary state (e,f,g,h).

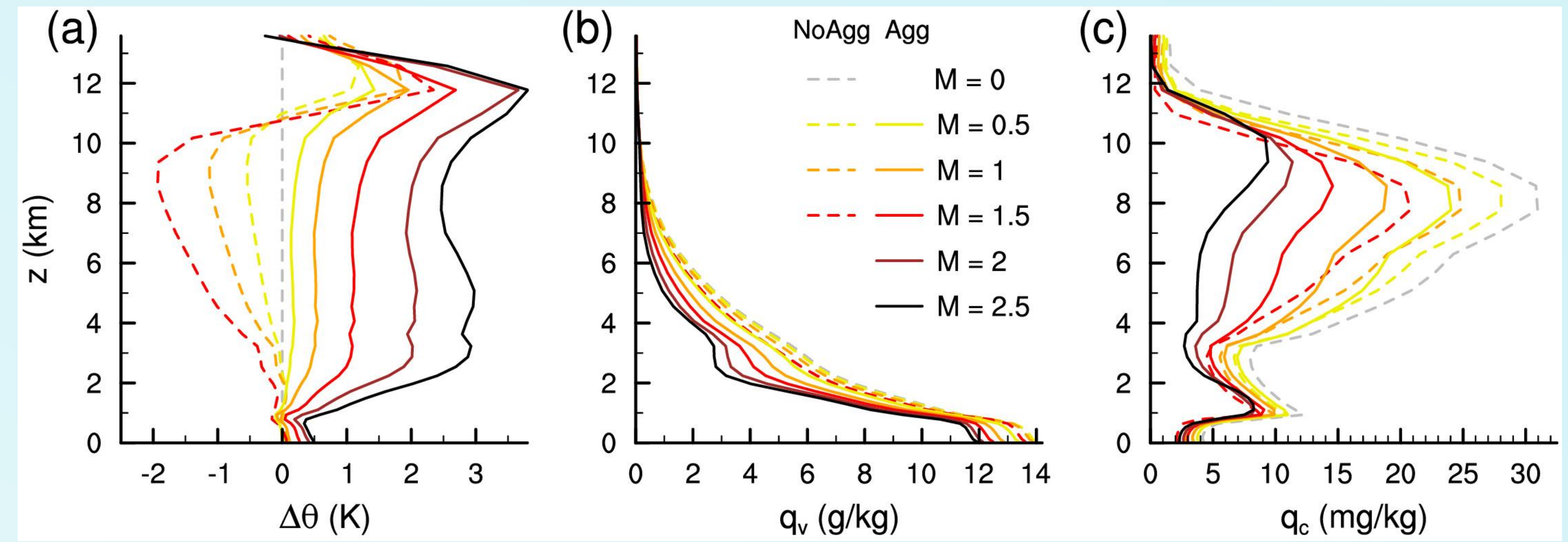

Figure 4: Profiles of (a) deviation of potential temperature from the RCE, (b) water vapor mixing ratio q_v, and (c) water condensate mixing ratio q_c for the non-aggregated (dashed lines) and the aggregated (solid lines) stationary states.

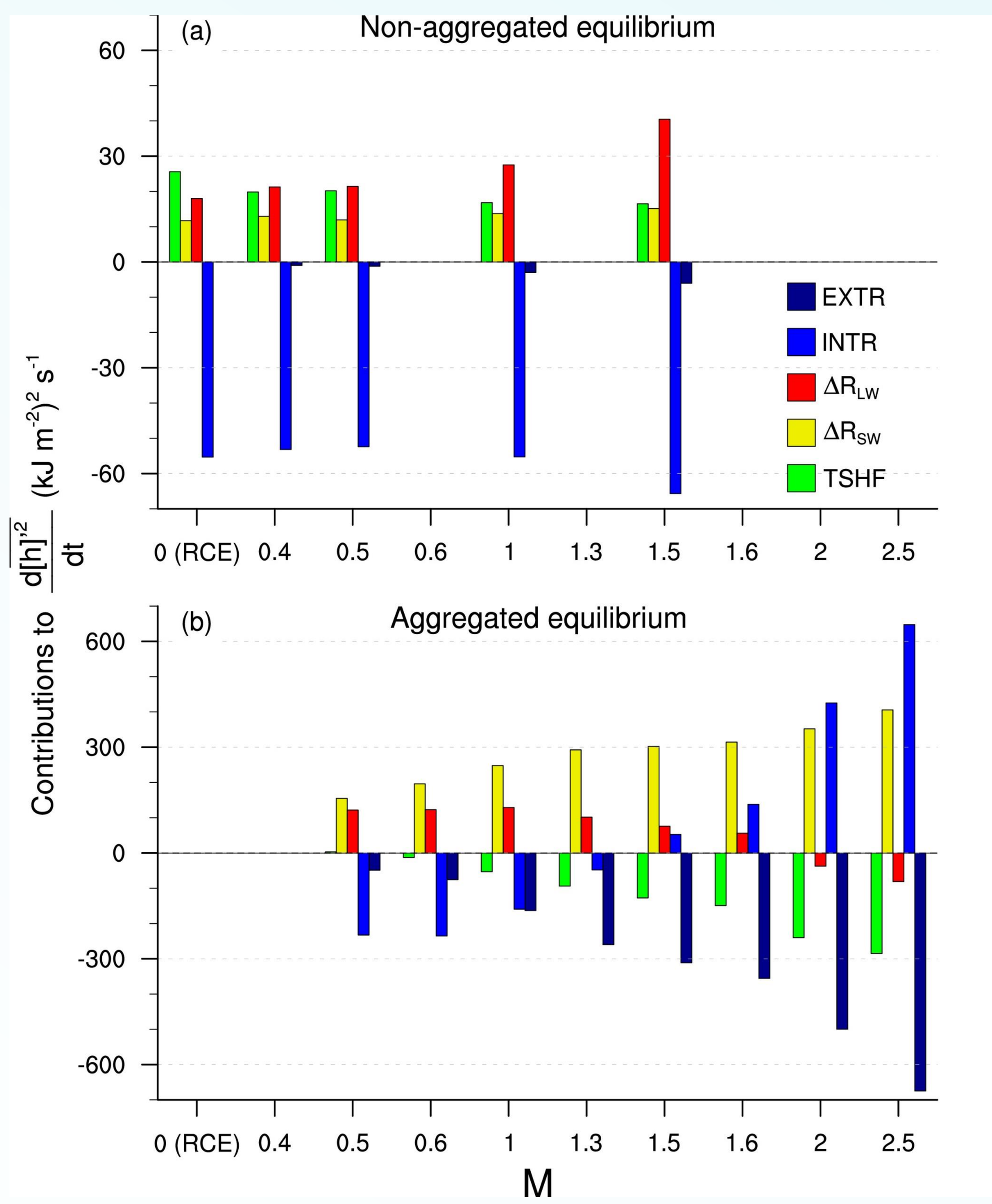

Figure 5: Contributions of the different processes to the (absence of) change in the variance $[h']^2$ of column-integrated MSE in (a) the non-aggregated stationary state and (b) the aggregated stationary state, for different values of the subsidence intensity.

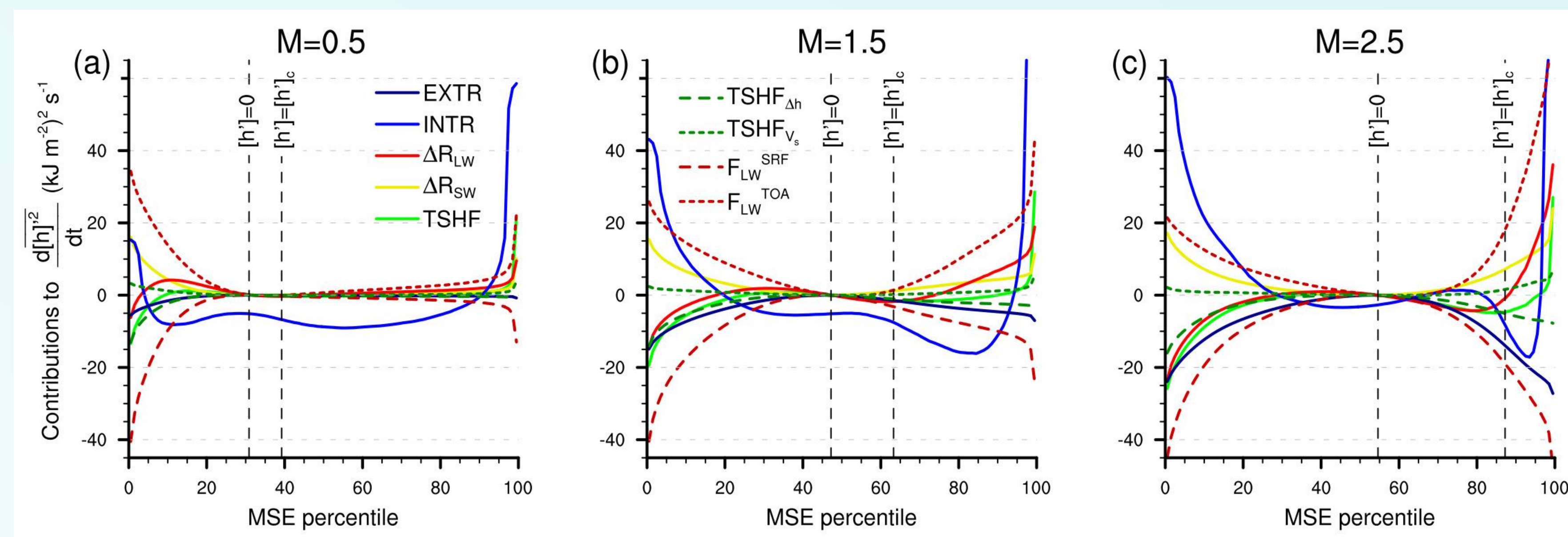

Figure 6: Contributions of the different processes to the change in the variance $[h']^2$ in the aggregated stationary state as a function of the percentile of [h], for (a) M= 0.5, (b) M= 1.5, and (c) M= 2.5

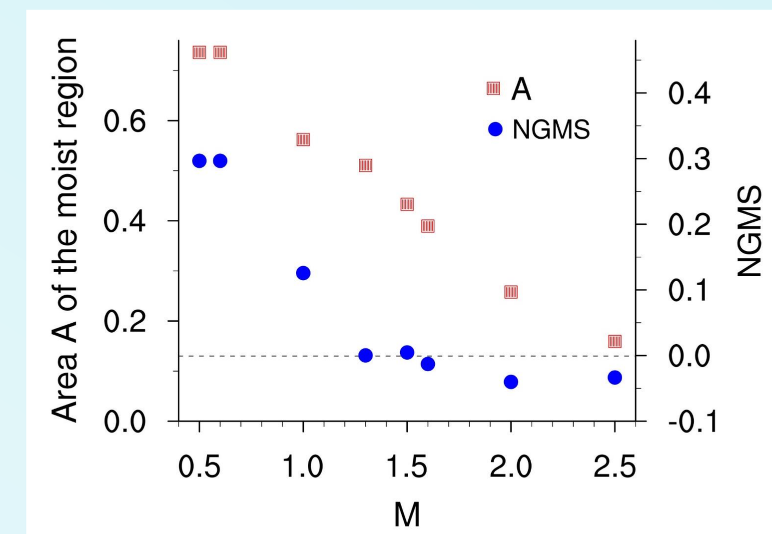

Figure 7: Fractional area A of the convective region and normalized gross convective stability NGMS associated with the internal circulation in the aggregated state as a function of M.

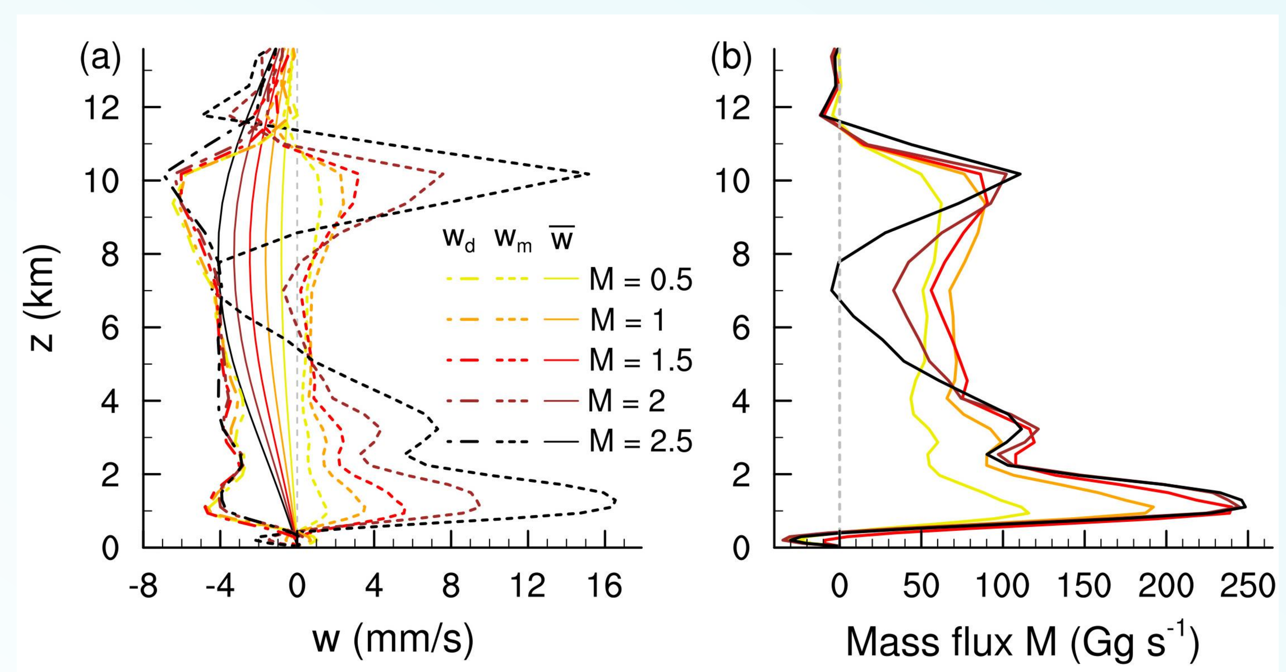

Figure 8: Profiles of (a) vertical velocity in the convective region w_c (dash-dotted lines), in the dry region (dotted lines), in average (solid lines), and (b) vertical internal mass flux in the convective region, in the aggregated stationary state for different values of M.

Conclusions

- **Subsidence favours aggregation** but it is not a linear sensitivity: there is a range of subsidence for which there are two stationary states, one aggregated, the other not (**Figure 3**)
- Both equilibria get drier with increasing subsidence, but aggregated equilibrium more than non-aggregated one (**Figure 4**).
- The area of the moist region in the aggregated equilibrium decreases with increasing subsidence (**Figure 7**).
- Non-aggregated states: all diabatic processes are positive feedbacks for self-aggregation while internal transport is the dominant negative feedback (**Figure 5**)
- Aggregated states (**Figures 5 and 6**): only SW is always a positive fb. Surface fluxes and external circ. are a negative fb. LW becomes a negative feedback with increasing M (competition between surface and TOA, **Figure 6**), while internal transport becomes a positive fb (intensifying shallow circulation (**Figure 8**) with negative NGMS (**Figure 7**)
- More: Transitions towards aggregagtion or disaggregation (ask! ☺)